MODIFIED CONVENTIONAL WET PRESSED TISSUE MACHINE

Background of the Invention

This application is a continuation of application serial number 10/199,778 entitled Method for Making Tissue Sheets on a Modified Conventional Crescent-Former Tissue Machine and filed in the U.S. Patent and Trademark Office on July 18, 2002, which is a divisional of application serial number 09/607,712 entitled "Method for Making Tissue Sheets on a Modified Conventional Crescent-Former Tissue Machine" and filed in the U.S. Patent and Trademark Office on June 30, 2000, the disclosures of which are hereby incorporated by reference. The present invention relates generally to methods and apparatus for making paper products. More particularly, the invention concerns methods for making cellulosic webs having high bulk and absorbency on a modified conventional wet-pressed machine and the apparatus to make the cellulosic web.

There are generally two different methods for making the base sheets for paper products such as paper towels, napkins, tissue, wipes and the like. These methods are commonly referred to as wet-pressing and throughdrying. While the two methods may be the same at the front end and back end of the process, they differ significantly in the manner in which water is removed from the wet web after its initial formation.

More specifically, in the wet-pressing method, the newly-formed wet web is typically transferred onto a papermaking felt and thereafter pressed against the surface of a steam-heated Yankee dryer while it is still supported by the felt. As the web is transferred to the surface of the Yankee dryer, water is expressed from the web and is absorbed by the felt. The dewatered web, typically having a consistency of about 40 percent, is then dried while on the hot surface of the Yankee dryer. The web is then creped to soften it and provide stretch to the resulting tissue sheet. A disadvantage of wet pressing is that the pressing step densifies the web, thereby decreasing the bulk and absorbency of the tissue sheet. The subsequent creping step only partially restores these desirable sheet properties.

In the throughdrying method, the newly-formed web is first dewatered using vacuum and then transferred to a relatively porous fabric and non-compressively dried by passing

hot air through the web. The resulting web can then be transferred to a Yankee dryer for creping. Because the web is substantially dry when transferred to the Yankee dryer, the density of the web is not significantly increased by the transfer. Also, the density of a throughdried tissue sheet is relatively low by nature because the web is dried while supported on the throughdrying fabric. The disadvantages of the throughdrying method are the relatively high operational energy costs and the capital costs associated with the throughdryers.

Because the vast majority of existing tissue machines utilize the older wet-pressing method, it is of particular importance that manufacturers find ways to modify existing wet-pressed machines to produce the consumer-preferred low-density products without expensive modifications to the existing machines. Of course, it is possible to re-build wet-pressed machines to throughdried configurations, but this is usually prohibitively expensive. Many complicated and expensive changes are necessary to accommodate the throughdryers and associated equipment. In addition, the length of a through-air dried tissue machine is greater, requiring a building addition or modification. In some locations, building modifications are not practical or possible, or prohibitively expensive because of the interference with other existing equipment or limited area available on the site. Accordingly, there has been great interest in finding ways to modify existing wet-pressed machines without significantly altering the machine design.

As a specific example, an approach to modifying a crescent-former tissue machine is particularly desirable, as there are many existing crescent-former tissue machines that could benefit from the consumer-preferred low-density products that can be made with the improved process. Many older crescent-former tissue machines were provided with a lower felt run that could be easily adapted to serve as an additional fabric run required for certain embodiments of this invention. This invention discloses a simple method for modifying a crescent-former tissue machine.

One simple approach to modifying a wet-pressed machine to produce softer, bulkier tissue is described in U.S. Patent 5,230,776 issued July 27, 1993 to Andersson et al. The patent discloses replacing the felt with a perforated belt of wire type and sandwiching the web between the forming wire and this perforated belt up to the press roll. The patent also appears to disclose additional dewatering means, such as a steam blowing tube, a blowing nozzle, and/or a separate press felt, that may be placed within the range of the sandwich structure in order to further increase the dry solids content before the Yankee

dryer. These extra drying devices are said to permit the machine to run at speeds at least substantially equivalent to the speed of throughdrying machines.

It is important to reduce the moisture content of the web coming onto the Yankee dryer, to maintain machine speed and to prevent blistering or lack of adhesion of the web. Referring to U.S. Patent 5,230,776, the use of a separate press felt, however, tends to densify the web in the same manner as a conventional wet-pressed machine. The densification resulting from a separate press felt would thus negatively impacting the bulk and absorbency of the web.

Further, jets of air for dewatering the web are not per se effective in terms of water removal or energy efficiency. Blowing air on the sheet for drying is well known in the art and used in the hoods of Yankee dryers for convective drying. In a Yankee dryer hood, however, the vast majority of the air from the jets does not penetrate the web. Thus, if not heated to high temperatures, most of the air would be wasted and not effectively used to remove water. In Yankee dryer hoods, the air is heated to as high as 900 degrees Fahrenheit and high residence times are allowed in order to effectuate drying.

Thus, what is lacking and needed in the art is a practical method for making tissue sheets having high bulk and absorbency comparable to throughdried sheets on a modified, conventional wet-pressed machine and an apparatus to produce the tissue sheets.

Summary of the Invention

It has now been discovered that a wet-pressed tissue can be made having bulk and absorbency properties equivalent to those of comparable throughdried products, while maintaining reasonable machine productivity. More particularly, wet-pressed cellulosic webs can be made by vacuum dewatering a wet web up to approximately 30 percent consistency, then using an integrally sealed air press to noncompressively dewater the sheet to 30 to 40 percent consistency. The wet web is desirably then transferred to a "molding" fabric substituted for the conventional wet-pressing felt in order to impart more contour or three-dimensionality to the wet web. The wet web is preferably thereafter pressed against the Yankee dryer while supported by the molding fabric and dried. The resulting product has exceptional wet bulk and absorbency exceeding that of conventional wet-pressed towels and tissue and equal to that of presently available throughdried products.

Hence in one aspect, the invention resides in an apparatus including: a forming roll; a drying cylinder positioned downstream of the forming roll; an air press positioned between the forming roll and the drying cylinder; a molding fabric adjacent a first fabric such that both fabrics travel through the air press, and wherein the air press is installed to direct a pressurized fluid through the molding fabric first and then through the first fabric; and a pressure roll adjacent the drying cylinder for pressing the molding fabric against the drying cylinder.

As used herein, “noncompressive dewatering” and “noncompressive drying” refer to dewatering or drying methods, respectively, for removing water from cellulosic webs that do not involve compressive nips or other steps causing significant densification or compression of a portion of the web during the drying or dewatering process.

The wet web is wet-molded in the process to improve the three-dimensionality and absorbent properties of the web. As used herein, "wet-molded" tissue sheets are those which are conformed to the surface contour of a molding fabric while at a consistency of about 30 to about 40 percent and then dried by thermal conductive drying means, such as a heated drying cylinder, as opposed to other drying means such as a throughdryer, before optional additional drying means.

The "molding fabrics" suitable for purposes of this invention include, without limitation, those papermaking fabrics which exhibit significant open area or three-dimensional surface contour sufficient to impart greater z-directional deflection of the web. Such fabrics include single-layer, multi-layer, or composite permeable structures. Preferred fabrics have at least some of the following characteristics: (1) On the side of the molding fabric that is in contact with the wet web (the top side), the number of machine direction (MD) strands per inch (mesh) is from 10 to 200 (3.94 to 78.74 per centimeter) and the number of cross-machine direction (CD) strands per inch (count) is also from 10 to 200 (3.94 to 78.74 per centimeter). The strand diameter is typically smaller than 0.050 inch (1.27 mm); (2) On the top side, the distance between the highest point of the MD knuckle and the highest point of the CD knuckle is from about 0.001 to about 0.02 or 0.03 inch (0.025 mm to about 0.508 mm or 0.762 mm). In between these two levels, there can be knuckles formed either by MD or CD strands that give the topography a 3-dimensional hill/valley appearance which is imparted to the sheet during the wet molding step; (3) On the top side, the length of the MD knuckles is equal to or longer than the length of the CD

knuckles; (4) If the fabric is made in a multi-layer construction, it is preferred that the bottom layer is of a finer mesh than the top layer so as to control the depth of web penetration and to maximize fiber retention; and, (5) The fabric may be made to show certain geometric patterns that are pleasing to the eye, which typically repeat between every 2 to 50 warp yarns.

The term "first fabric" is used herein to refer to any fabric used in tissue making as described herein or known in the art, including, but not limited to, forming, molding, and other support fabrics used in making tissue. However, the first fabric is preferably a forming fabric. The term "second fabric" is used herein to refer to any fabric used in tissue making as described herein or known in the art, including, but not limited to, forming, molding, and other support fabrics used in making tissue. However, the second fabric is preferably a molding fabric as described herein. Where the second fabric is a molding fabric, the resulting web is a molded web. The term "support fabric" is used herein to refer to any fabric used in tissue making as described herein or known in the art, including, but not limited to, forming, molding, or any other fabric used in making tissue.

The terms "integral seal" and "integrally sealed" are used herein to refer to: the relationship between the air plenum and the wet web where the air plenum is operatively associated and in indirect contact with the web such that about 85 percent or greater of the air fed to the air plenum flows through the web when the air plenum is operated at a pressure differential across the web of about 30 inches of mercury or greater; and, the relationship between the air plenum and the collection device where the air plenum is operatively associated and in indirect contact with the web and the collection device such that about 85 percent or greater of the air fed to the air plenum flows through the web into the collection device when the air plenum and collection device are operated at a pressure differential across the web of about 30 inches of mercury or greater.

The air press is able to dewater the wet web to very high consistencies due in large part to the high pressure differential established across the web and the resulting air flow through the web. In particular embodiments, for example, the air press can increase the consistency of the wet web by about 3 percent or greater, particularly about 5 percent or greater, such as from about 5 to about 20 percent, more particularly about 7 percent or greater, and more particularly still about 7 percent or greater, such as from about 7 to 20 percent. Thus, the consistency of the wet web upon exiting the air press may be about 25 percent or greater, about 26 percent or greater, about 27 percent or greater, about 28

percent or greater, about 29 percent or greater, and is desirably about 30 percent or greater, particularly about 31 percent or greater, more particularly about 32 percent or greater, such as from about 32 to about 42 percent, more particularly about 33 percent or greater, even more particularly about 34 percent or greater, such as from about 34 to about 42 percent, and still more particularly about 35 percent or greater.

By adding the integrally sealed air press dewatering step to the process, considerable improvements over the previously described existing processes can be achieved. First, and most importantly, a high enough consistency is achieved so that the process can operate at industrially useful speeds. As used herein, “high-speed operation” or “industrially useful speed” for a tissue machine refers to a machine speed at least as great as any one of the following values or ranges, in feet per minute: 1,000; 1,500; 2,000; 2,500; 3,000; 3,500; 4,000; 4,500; 5,000, 5,500; 6,000; 6,500; 7,000; 8,000; 9,000; 10,000, and a range having an upper and a lower limit of any of the above listed values. Further, molding the sheet at high consistencies significantly improves the ability of the sheet to retain its three-dimensionality and thus also significantly improves the resulting caliper of the sheet. As used herein, the term “textured” or “three-dimensional” as applied to the surface of a fabric, felt, or uncalendered paper web, indicates that the surface is not substantially smooth and coplanar. Additionally, the present machine configuration is amenable to incorporating a rush transfer step, which again results in a significant increase in bulk and absorbency relative to the existing wet pressing processes.

Optional steam showers or the like may be employed before the air press to increase the post air press consistency and/or to modify the cross-machine direction moisture profile of the web. Furthermore, higher consistencies may be achieved when machine speeds are relatively low and the dwell time in the air press is relatively high.

The pressure differential across the wet web provided by the air press may be about 25 inches of mercury or greater, such as from about 25 to about 120 inches of mercury, particularly about 35 inches of mercury or greater, such as from about 35 to about 60 inches of mercury, and more particularly from about 40 to about 50 inches of mercury. This may be achieved in part by an air plenum of the air press maintaining a fluid pressure on one side of the wet web of greater than 0 to about 60 pounds per square inch gauge (psig), particularly greater than 0 to about 30 psig, more particularly about 5 psig or greater, such as about 5 to about 30 psig, and more particularly still from about 5 to about 20 psig. The collection device of the air press desirably functions as a vacuum

box operating at 0 to about 29 inches of mercury vacuum, particularly 0 to about 25 inches of mercury vacuum, particularly greater than 0 to about 25 inches of mercury vacuum, and more particularly from about 10 to about 20 inches of mercury vacuum, such as about 15 inches of mercury vacuum. In some embodiments, the collection device of the air press may operate at 30 inches of mercury vacuum or greater. The collection device desirably but not necessarily forms an integral seal with the air plenum and draws a vacuum to facilitate its function as a collection device for air and liquid. Both pressure levels within both the air plenum and the collection device are desirably monitored and controlled to predetermined levels.

Significantly, the pressurized fluid used in the air press is sealed from ambient air to create a substantial air flow through the web, which results in the tremendous dewatering capability of the air press. The flow of pressurized fluid through the air press is suitably from about 5 to about 500 standard cubic feet per minute (SCFM) per square inch of open area, particularly about 10 SCFM per square inch of open area or greater, such as from about 10 to about 200 SCFM per square inch of open area, and more particularly about 40 SCFM per square inch of open area or greater, such as from about 40 to about 120 SCFM per square inch of open area. Desirably, of the pressurized fluid supplied to the air plenum, 70 percent or greater, particularly 80 percent or greater, and more particularly 90 percent or greater, is drawn through the wet web into the vacuum box. For purposes of the present invention, the term “standard cubic feet per minute” means cubic feet per minute measured at 14.7 pounds per square inch absolute and 60 degrees Fahrenheit (°F).

The terms “air” and “pressurized fluid” are used interchangeably herein to refer to any gaseous substance used in the air press to dewater the wet web. The gaseous substance suitably comprises air, steam or the like. Desirably, the pressurized fluid comprises air at ambient temperature, or air heated only by the process of pressurization to a temperature of about 300 ° F or less, more particularly about 150 ° F or less.

The wet web is desirably attached to the Yankee dryer or other heated drying cylinder surface in a manner that preserves a substantial portion of the texture imparted by previous treatments, especially the texture imparted by molding on three-dimensional fabrics. The conventional manner used to produce wet-pressed creped paper is inadequate for this purpose, for in that method, a pressure roll is used to dewater the wet web and to uniformly press the wet web into a dense, flat state. For the present invention,

the conventional substantially smooth press felt of the conventional crescent-former tissue machine is replaced with a textured material such as a foraminous fabric and desirably a throughdrying fabric. Tissue webs made according to the present method desirably have a bulk after being molded onto the three-dimensional fabric of about 8 cubic centimeters per gram (cc/g) or greater, particularly about 10 cc/g or greater, and more particularly about 12 cc/g or greater, and that bulk is maintained after being pressed onto the heated drying cylinder using the textured foraminous fabric.

For best results, significantly lower pressing pressures can be used as compared to conventional tissue making. Desirably, the zone of maximum load applied to the web should be about 400 psi or less, particularly about 350 psi or less, more particularly about 150 psi or less, such as between about 2 and about 50 psi, and most particularly about 30 psi or less, when averaged across any one-inch square region encompassing the point of maximum pressure. The pressing pressures measured in pounds per lineal inch (pli) at the point of maximum pressure are desirably about 400 pli or less, and particularly about 350 pli or less. Low-pressure application of a three-dimensional web structure onto a heated drying cylinder helps to maintain substantially uniform density in the dried web. Substantially uniform density is promoted by effectively dewatering the web with noncompressive means prior to the Yankee dryer attachment, and by selecting a foraminous fabric to contact the web against the dryer that is relatively free of high, inflexible protrusions that could apply high local pressure to the web. The fabric is desirably treated with an effective amount of a fabric release agent to promote detachment of the web from the fabric once the web contacts the dryer surface.

The absorbency of a tissue sheet may be characterized by its Absorbent Capacity and its Absorbent Rate. As used herein, "Absorbent Capacity" is the maximum amount of distilled water which a sheet can absorb, expressed as grams of water per gram of sample sheet. More specifically, the Absorbent Capacity of a sample sheet can be measured by cutting a 4 inch by 4 inch (101.6 by 101.6 mm) sample of the dry sheet and weighing it to the nearest 0.01 gram. The sample is dropped onto the surface of a room temperature distilled water bath and left in the bath for 3 minutes. The sample is then removed using tongs or tweezers and suspended vertically using a 3-prong clamp to drain excess water. Each sample is allowed to drain for 3 minutes. The sample is then placed in a weighing dish by holding the weighing dish under the sample and releasing the clamp. The wet sample is weighed to the nearest 0.01 gram. The Absorbent Capacity is the wet weight of the sample minus the dry weight (the amount of water absorbed), divided by the dry

weight of the sample. At least five representative samples of each product should be tested and the results averaged.

The "Absorbent Rate" is the time it takes for a product to become thoroughly wetted out in distilled water. It is determined by dropping a pad comprised of twenty sheets, each measuring 2.5 inches by 2.5 inches (63.5 by 63.5 mm), onto the surface of a distilled water bath having a temperature of 30 °C. The elapsed time, in seconds, from the moment the sample hits the water until it is completely wetted (as determined visually) is the Absorbent Rate.

The present method is useful to make a variety of absorbent products, including facial tissue, bath tissue, towels, napkins, wipes, or the like. For purposes of the present invention, the terms “tissue” or “tissue products” are used generally to describe such product structures, and the term “cellulosic web” is used to broadly refer to webs comprising or consisting of cellulosic fibers regardless of the finished product structure.

Many fiber types may be used for the present invention including hardwood or softwoods, straw, flax, milkweed seed floss fibers, abaca, hemp, kenaf, bagasse, cotton, reed, and the like. All known papermaking fibers may be used, including bleached and unbleached fibers, fibers of natural origin (including wood fiber and other cellulosic fibers, cellulose derivatives, and chemically stiffened or crosslinked fibers) or synthetic fibers (synthetic papermaking fibers include certain forms of fibers made from polypropylene, acrylic, aramids, acetates, and the like), virgin and recovered or recycled fibers, hardwood and softwood, and fibers that have been mechanically pulped (e.g., groundwood), chemically pulped (including but not limited to the kraft and sulfite pulping processes), thermomechanically pulped, chemithermomechanically pulped, and the like. The mixtures of any subset of the above mentioned or related fiber classes may be used. The fibers can be prepared in a multiplicity of ways known to be advantageous in the art. Useful methods of preparing fibers include dispersion to impart curl and improved drying properties, such as disclosed in U.S. Patents 5,348,620 issued September 20, 1994 and 5,501,768 issued March 26, 1996, both to M. A. Hermans et al.

Chemical additives may be also be used and may be added to the original fibers, to the fibrous slurry or added on the web during or after production. Such additives include opacifiers, pigments, wet strength agents, dry strength agents, softeners, emollients, humectants, viricides, bactericides, buffers, waxes, fluoropolymers, odor control materials

and deodorants, zeolites, dyes, fluorescent dyes or whiteners, perfumes, debonders, vegetable and mineral oils, humectants, sizing agents, superabsorbents, surfactants, moisturizers, UV blockers, antibiotic agents, lotions, fungicides, preservatives, aloe-vera extract, vitamin E, or the like. The application of chemical additives need not be uniform, but may vary in location and from side to side in the tissue. Hydrophobic material deposited on a portion of the surface of the web may be used to enhance properties of the web.

The headbox may be stratified to permit production of a multilayered structure from a single headbox jet in the formation of a web. In particular embodiments, the web is produced with a stratified or layered headbox to preferentially deposit shorter fibers on one side of the web for improved softness, with relatively longer fibers on the other side of the web or in an interior layer of a web having three or more layers. The web is desirably formed on an endless loop of foraminous forming fabric which permits drainage of the liquid and partial dewatering of the web.

Numerous features and advantages of the present invention will appear from the following description. In the description, reference is made to the accompanying drawings which illustrate preferred embodiments of the invention. Such embodiments do not represent the full scope of the invention. Reference should therefore be made to the claims herein for interpreting the full scope of the invention.

Brief Description of the Drawings

Figure 1 representatively shows a schematic process flow diagram illustrating a method according to the present invention for making cellulosic webs having high bulk and absorbency.

Figure 2 representatively shows a schematic process flow diagram illustrating an alternative method according to the present invention.

Figure 3 representatively shows a schematic process flow diagram illustrating yet another alternative method according to the present invention.

Figure 4 representatively shows an enlarged end view of an air press for use in the methods of **Figures 1 - 3**, with an air plenum sealing assembly of the air press in a raised position relative to the wet web and vacuum box.

Figure 5 representatively shows a side view of the air press of **Figure 4**.

Figure 6 representatively shows an enlarged section view taken generally from the plane of the line 6 - 6 in **Figure 4**, but with the sealing assembly loaded against the fabrics.

Figure 7 representatively shows an enlarged section view similar to **Figure 6** but taken generally from the plane of the line 7 - 7 in **Figure 4**.

Figure 8 representatively shows a perspective view of several components of the air plenum sealing assembly positioned against the fabrics, with portions broken away and shown in section for purposes of illustration.

Figure 9 representatively shows an enlarged section view of an alternative sealing configuration for the air press of **Figure 4**.

Figure 10 representatively shows an enlarged schematic diagram of a sealing section of the air press of **Figure 4**.

Detailed Description of the Drawings

The invention will now be described in greater detail with reference to the Figures, where similar elements in different Figures have been given the same reference numeral. For simplicity, the various tensioning rolls schematically used to define the several fabric runs are shown but not numbered. A variety of conventional papermaking apparatuses and operations can be used with respect to the stock preparation, headbox, forming fabrics, web transfers, creping and drying. Nevertheless, particular conventional components are illustrated for purposes of providing the context in which the various embodiments of the invention can be used.

The process of the present invention may be carried out on an apparatus as shown in **Figure 1** modified from a typical crescent-former tissue paper machine. An embryonic wet web **10** formed as a slurry of papermaking fibers is deposited from a headbox **12** between an endless loop of a first fabric **14** and an endless loop of a second fabric **24**. The second fabric **24** generally replaces the felt of a standard crescent-former tissue machine. The consistency and flow rate of the slurry determines the dry web basis weight, which desirably is between about 5 and about 80 grams per square meter (gsm), and more desirably between about 8 and about 40 gsm. At least one of the fabrics **14** and **24** may be a forming fabric, preferably the first fabric **14**. In addition, at least one of the fabrics **14** and **24** may be a molding fabric, preferably the second fabric **24**.

The embryonic wet web **10** is partially dewatered by the pressure due to the tension on the first fabric **14** and the centrifugal force created as the wet web **10** passes around the forming roll **52** while the wet web **10** is carried between the first fabric **14** and the second fabric **24**. Once the partial dewatering step is completed, the wet web **10** is transferred to or retained on the second fabric **24** with or without the use of a vacuum shoe **50**.

For high-speed operation of the present invention, conventional tissue dewatering methods prior to the heated drying cylinder **30** may give inadequate water removal, so additional dewatering devices or means may be needed. In the illustrated embodiment, an air press **16** is used to noncompressively dewater the wet web **10**. The illustrated air press **16** comprises an assembly of a pressurized air plenum **18** disposed above the wet web **10**, a fluid collection device **20**, shown in the form of a vacuum box, disposed beneath a support fabric **22** in operable relation with the pressurized air plenum **18** and the second fabric **24**. (In alternative embodiments, the fluid collection device **20** may be disposed next to the second fabric **24** in operable relation with the pressurized air plenum **18** and the support fabric **22**). While passing through the air press **16**, the wet web **10** is sandwiched between the second fabric **24** and the support fabric **22** in order to facilitate sealing against the wet web **10** without damaging the wet web **10**.

The air press **16** provides substantial rates of water removal, enabling the web to achieve dryness levels well over 30 percent prior to attachment to the drying cylinder **30**, such as a Yankee dryer, desirably without the requirement for substantial compressive dewatering. Several embodiments of the air press **16** are described in greater detail hereinafter. Other suitable embodiments are disclosed in U.S. Patent Application Serial

No. 08/647,508 filed May 14, 1996 by M.A. Hermans et al. titled "Method and Apparatus for Making Soft Tissue," which is incorporated herein by reference.

Following the air press **16**, the wet web **10** travels further with the second fabric **24** and the support fabric **22** until the wet web **10** is transferred back to the second fabric **24**, preferably a textured fabric, with or without the assistance of a vacuum transfer shoe **26** at a transfer station.

The second fabric **24** may comprise a three-dimensional throughdrying fabric such as those disclosed in U.S. Patent 5,429,686 issued July 4, 1995 to K. F. Chiu et al., which is incorporated herein by reference, or may comprise other woven, textured webs or nonwoven fabrics. The second fabric **24** may be treated with a fabric release agent such as a mixture of silicones or hydrocarbons to facilitate subsequent release of the wet web **10** from the second fabric **24**. The fabric release agent can be sprayed on the second fabric **24** prior to the pick-up of the web. Once on the second fabric **24**, the wet web **10** may be further molded against the second fabric **24** through application of vacuum pressure or light pressing (not shown), though the molding that occurs at least due to vacuum forces at the transfer shoe **26** during pick-up may be adequate to mold the wet web **10**.

The wet web **10** on the second fabric **24** is then pressed against a drying cylinder **30** by means of a pressure roll **32**. The drying cylinder **30** is equipped with a vapor hood or Yankee dryer hood **34**. The hood **34** typically employs jets of heated air at temperatures about 300 °F or greater, particularly about 400 °F or greater, more particularly about 500 °F or greater, and most particularly about 700 °F or greater, which are directed toward the tissue web **10** from nozzles or other flow devices such that the air jets have maximum or locally averaged velocities in the hood **34** of one of the following levels: about 10 meters per second (m/s) or greater, about 50 m/s or greater, about 100 m/s or greater, or about 250 m/s or greater.

The wet web **10** when affixed to the heated drying cylinder **30** suitably has a fiber consistency of about 30 percent or greater, particularly about 35 percent or greater, such as between about 35 and about 50 percent, and more particularly about 38 percent or greater. The dryness of the wet web **10** upon being removed from the heated drying cylinder **30** is increased to about 60 percent or greater, particularly about 70 percent or greater, more particularly about 80 percent or greater, more particularly still about 90

percent or greater, and most particularly between about 90 and about 98 percent. The wet web **10** can be partially dried on the heated drying cylinder **30** and wet creped at a consistency of about 40 to about 80 percent and thereafter dried (after-dried) to a consistency of about 95 percent or greater. Non-traditional hoods and impingement systems can be used as an alternative to or in addition to the Yankee dryer hood **34** to enhance drying of the wet web **10**. Additional heated drying cylinders **30** or other drying means, particularly noncompressive drying, may be used after the first heated drying cylinder **30**. Suitable means for after-drying include one or more heated drying cylinders **30**, such as Yankee dryers and can dryers, throughdryers, or any other commercially effective drying means. Alternatively, the wet web **10**, which may be molded if the second fabric **24** is a molding fabric, can be completely dried on the heated drying cylinder **30** and dry creped. The amount of drying on the heated drying cylinder **30** will depend on such factors as the speed of the wet web **10**, the size of the heated drying cylinder **30**, the amount of moisture in the wet web **10**, and the like.

The resulting dried web **36** is drawn or conveyed from the heated drying cylinder **30**, for example by a creping blade **28**, after which it is reeled onto a roll **38**. An interfacial control mixture **40** is illustrated being applied to the surface of the rotating heated drying cylinder **30** in spray form from a spray boom **42** prior to the wet web **10** contacting the surface of the heated drying cylinder **30**. As an alternative to spraying directly on the surface of the heated drying cylinder **30**, the interfacial control mixture **40** could be applied directly to either the wet web **10** or the surface of the heated drying cylinder **30** by gravure printing or could be incorporated into the aqueous fibrous slurry in the wet end of the paper machine. While on the surface of the heated drying cylinder **30**, the wet web **10** may be further treated with chemicals, such as by printing or direct spray of solutions onto the drying web **10**, including the addition of agents to promote release from the surface of the heated drying cylinder **30**.

The interfacial control mixture **40** may comprise a conventional creping adhesive and/or dryer release agent for wet-pressed and creped operation. The dried web **36** may also be removed from the surface of the heated drying cylinder **30** without creping using an interfacial control mixture **40** of the type disclosed in U.S. Patent Application Serial No. unknown filed on the same day as the present application by F. G. Druecke et al. titled “Method Of Producing Low Density Resilient Webs,” which is incorporated herein by reference.

An alternative embodiment is shown in **Figure 2**, where an embryonic wet web **10** formed as a slurry of papermaking fibers is deposited from a headbox **12** between an endless loop of a first fabric **14** and an endless loop of a second fabric **24**. The second fabric **24** generally replaces the felt of the standard crescent-former tissue machine. At least one of the fabrics **14** and **24** may be a forming fabric, preferably the first fabric **14**. In addition, at least one of the fabrics **14** and **24** may be a molding fabric, preferably the second fabric **24**.

The embryonic wet web **10** is partially dewatered by the pressure due to tension on the first fabric **14** and the centrifugal force created as the wet web **10** passes around the forming roll **52** while the wet web **10** is carried between the first fabric **14** and the second fabric **24**. Once the partial dewatering step is completed, the wet web **10** is optionally further dewatered by a vacuum box **46** or other suitable devices while between the first fabric **14** and the second fabric **24** and is transferred to or retained on the second fabric **24** with or without the use of a vacuum shoe **50**.

An air press **16** is used to noncompressively dewater the wet web **10** as it is sandwiched between the second fabric **24** and a support fabric **22**. The illustrated air press **16** comprises an assembly of a pressurized air plenum **18** disposed in operable relation with a vacuum box **20**. While passing through the air press **16**, the wet web **10** is sandwiched between the second fabric **24** and the support fabric **22** with the support fabric **22** disposed between the wet web **10** and the vacuum box **20**. (In alternative embodiments, the second fabric **24** may be disposed between the wet web **10** and the vacuum box **20**).

The wet web **10** is then transferred with or without the assistance of the vacuum shoe **26** to the second fabric **24**. A roll **55** of the run of the support fabric **22** is so oriented to change the direction of the second fabric **24**, the support fabric **22**, and the wet web **10** such that the wet web **10** is less likely to be released from the suction pressure roll **32** before the wet web **10** is transferred to the Yankee dryer or other heated drying cylinder **30**. The roll **55** reduces the unsupported sheet wrap angle α thereby minimizes the opportunity of the wet web **10** to separate from the second fabric **24** before the wet web **10** is transferred to the heated drying cylinder **30**.

The wet web **10** on the second fabric **24** is then pressed against a heated drying cylinder **30** by means of a pressure roll **32**. The wet web **10** on the second fabric **24** is

then pressed against a drying cylinder **30** by means of a pressure roll **32**, preferably in a manner to minimized the unsupported sheet wrap angle α on the pressure roll **32**. The unsupported sheet wrap angle α may range from 0 to about 90 degrees, from 0 to about 45 degrees, and from 0 to about 10 degrees. Additionally, lower unsupported sheet wrap angle α reduces the size of the vacuum zone required thereby reducing energy requirements for the vacuum generated in the pressure roll. The unsupported sheet wrap angle α is defined as the portion of the circumference of the pressure roll **32** (expressed in degrees) wrapped by the wet web **10** from the first contact point of the wet web **10** on the pressure roll **32** to the last contact point of the wet web **10** on the pressure roll **32** as the wet web **10** is transferred to the drying cylinder **30**.

The heated drying cylinder **30** is equipped with a vapor hood or Yankee dryer hood **34**. The resulting dried web **36** is drawn or conveyed from the heated drying cylinder **30** and removed without creping, after which it is reeled onto a roll **38**. The angle at which the dried web **36** is pulled from the surface of the heated drying cylinder **30** is suitably about 80 to about 100 degrees, measured tangent to the surface of the heated drying cylinder **30** at the point of separation, although this may vary at different operating speeds.

An interfacial control mixture **40** may be applied to the surface of the rotating heated drying cylinder **30** in spray form from a spray boom **42**. For example, the interfacial control mixture **40** may comprise a mixture of polyvinyl alcohol, sorbitol, and Hercules M1336 polyglycol applied in an aqueous solution having less than 5 percent solids by weight, at a dose of between 50 and 75 milligrams per square meter. The amount of adhesive compounds and release agents must be balanced to adhere the wet web **10** so that is does not go up into the hood **34** yet to permit the dried web **36** to be pulled off the heated drying cylinder **30** without creping.

Another alternative embodiment is shown in **Figure 3**. This embodiment is similar to that of **Figure 2** except that the first fabric **14** is extended to act as the support fabric **22** shown in **Figure 2**. This provides a potential reduction in capital cost and operating cost with the reduction in the number of fabrics required to modify this process. In the embodiment shown in **Figure 3**, an embryonic wet web **10** formed as a slurry of papermaking fibers is deposited from a headbox **12** between an endless loop of a first fabric **14** and an endless loop of a second fabric **24**. The second fabric **24** generally replaces the felt of the standard crescent-former tissue machine. At least one of the fabrics **14** and **24** may be a forming fabric, preferably the first fabric **14**. In addition, at

least one of the fabrics **14** and **24** may be a molding fabric, preferably the second fabric **24**.

The embryonic wet web **10** is partially dewatered by the pressure due to the tension on first fabric **14** and the centrifugal force created as the wet web **10** passes around the forming roll **52** and further dewatered by an optional vacuum box **46** or other suitable devices while between the first fabric **14** and the second fabric **24**. An air press **16** is used to non-compressively dewater the wet web **10** as it is sandwiched between the first fabric **14** and a second fabric **24**. The illustrated air press **16** comprises an assembly of a pressurized air plenum **18** disposed in operable relation with a vacuum box **20**. While passing through the air press **16**, the wet web **10** is sandwiched between the second fabric **24** and the support fabric **22** with the support fabric **22** disposed between the wet web **10** and the vacuum box **20**. (In alternative embodiments, the second fabric **24** may be disposed between the wet web **10** and the vacuum box **20**).

The wet web **10** is then transferred with or without the assistance of the vacuum shoe **26** to the second fabric **24**. The wet web **10** on the second fabric **24** is then pressed against a drying cylinder **30** by means of a pressure roll **32**. The heated drying cylinder **30** is equipped with a vapor hood or Yankee dryer hood **34**. The resulting dried web **36** is drawn or conveyed from the heated drying cylinder **30** and removed without creping, after which it is reeled onto a roll **38**. The angle at which the dried web **36** is pulled from the surface of the heated drying cylinder **30** is suitably about 80 to about 100 degrees, measured tangent to the surface of the heated drying cylinder **30** at the point of separation, although this may vary at different operating speeds.

An interfacial control mixture **40** may be applied to the surface of the rotating heated drying cylinder **30** in spray form from a spray boom **42**. For example, the interfacial control mixture **40** may comprise a mixture of polyvinyl alcohol, sorbitol, and Hercules M1336 polyglycol applied in an aqueous solution having less than 5 percent solids by weight, at a dose of between 50 and 75 milligrams per square meter. The amount of adhesive compounds and release agents must be balanced to adhere the wet web **10** so that is does not go up into the hood **34** yet to permit the dried web **36** to be pulled off the heated drying cylinder **30** without creping.

An air press **200** for dewatering the wet web **10** is shown in **Figures 4 - 7**. The air press **200** generally comprises an upper air plenum **202** in combination with a lower

collection device **204** in the form of a vacuum box. The wet web **10** travels in a machine direction **205** between the air plenum **202** and vacuum box **204** while sandwiched between an upper support fabric **206** and a lower support fabric **208**. The air plenum **202** and vacuum box **204** are operatively associated with one another so that pressurized fluid supplied to the air plenum **202** travels through the wet web **10** and is removed or evacuated through the vacuum box **204**.

Each continuous fabrics **206** and **208** travels over a series of rolls (not shown) to guide, drive and tension the fabrics **206** and **208** in a manner known in the art. The fabric tension is set to a predetermined amount, suitably from about 10 to about 60 pounds per lineal inch (pli), particularly from about 30 to about 50 pli, and more particularly from about 35 to about 45 pli. The fabrics **206** and **208** that may be useful for transporting the wet web **10** through the air press **200** include almost any fluid permeable fabric, for example Albany International 94M, Appleton Mills 2164B, or the like.

An end view of the air press **200** spanning the width of the wet web **10** is shown in **Figure 4**, and a side view of the air press **200** in the machine direction **205** is shown in **Figure 5**. In both **Figures 4** and **5**, several components of the air plenum **202** are illustrated in a raised or retracted position relative to the wet web **10** and the vacuum box **204**. In the retracted position, effective sealing of pressurized fluid is not possible. For purposes of the present invention, a “retracted position” of the air press **200** means that the components of the air plenum **202** do not impinge upon the wet web **10** and support fabrics **206** and **208**.

The illustrated air plenum **202** and the vacuum box **204** are mounted within a suitable frame structure **210**. The illustrated frame structure **210** comprises upper and lower support plates **211** separated by a plurality of vertically oriented support bars **212**. The air plenum **202** defines a plenum chamber **214** (**Figure 7**) that is adapted to receive a supply of pressurized fluid through one or more suitable air conduits **215** operatively connected to a pressurized fluid source (not shown). Correspondingly, the vacuum box **204** defines a plurality of vacuum chambers (described hereinafter in relation to **Figure 7**) that are desirably operatively connected to low and high vacuum sources (not shown) by suitable fluid conduits **217** and **218**, respectively (**Figures 5**, **6**, and **7**). The water removed from the wet web **10** is thereafter separated from the air streams. Various fasteners for mounting the components of the air press **200** are shown in the **Figures 5**, **6**, and **7** but are not labeled.

Enlarged section views of the air press **200** are shown in **Figures 6** and **7**. In these **Figures 6** and **7**, the air press **200** is shown in an operating position wherein components of the air plenum **202** are lowered into an impingement relationship with the wet web **10** and support fabrics **206** and **208**. The degree of impingement that has been found to result in proper sealing of the pressurized fluid with minimal contact force and therefore reduced fabric wear is described in greater detail hereinafter.

The air plenum **202** comprises both stationary components **220** that are fixedly mounted to the frame structure **210** and a sealing assembly **260** that is movably mounted relative to the frame structure **210** and the wet web **10**. Alternatively, the entire air plenum **202** could be moveably mounted relative to a frame structure **210**.

With particular reference to **Figure 7**, the stationary components **220** of the air plenum **202** include a pair of upper support assemblies **222** that are spaced apart from one another and positioned beneath the upper support plate **211**. The upper support assemblies **222** define facing surfaces **224** that are directed toward one another and that partially define therebetween the plenum chamber **214**. The upper support assemblies **222** also define bottom surfaces **226** that are directed toward the vacuum box **204**. In the illustrated embodiment, each bottom surface **226** defines an elongated recess **228** in which an upper pneumatic loading tube **230** is fixedly mounted. The upper pneumatic loading tubes **230** are suitably centered the cross-machine direction and desirably extend over the full width of the wet web **10**.

The stationary components **220** of the air plenum **202** also include a pair of lower support assemblies **240** that are spaced apart from one another and vertically spaced from the upper support assemblies **222**. The lower support assemblies **240** define top surfaces **242** and facing surfaces **244**. The top surfaces **242** are directed toward the bottom surfaces **226** of the upper support assemblies **222** and, as illustrated, define elongated recesses **246** in which lower pneumatic loading tubes **248** are fixedly mounted. The lower pneumatic loading tubes **248** are suitably centered in the cross-machine direction and suitably extend over about 50 to 100 percent of the width of the wet web. In the illustrated embodiment, lateral support plates **250** are fixedly attached to the facing surfaces **244** of the lower support assemblies **240** and function to stabilize vertical movement of the sealing assembly **260**.

With additional reference to **Figure 8**, the sealing assembly **260** comprises a pair of cross-machine direction sealing members referred to as CD sealing members **262** (**Figures 6** - **8**) that are spaced apart from one another, a plurality of braces **263** (**Figure 8**) that connect the CD sealing members **262**, and a pair of machine direction sealing members referred to as MD sealing members **264** (**Figures 6** and **8**). The CD sealing members **262** are vertically moveable relative to the stationary components **220**. The optional but desirable braces **263** are fixedly attached to the CD sealing members **262** to provide structural support, and thus move vertically along with the CD sealing members **262**. In the machine direction **205**, the MD sealing members **264** are disposed between the upper support assemblies **222** and between the CD sealing members **262**. As described in greater detail hereinafter, portions of the MD sealing members **264** are vertically moveable relative to the stationary components **220**. In the cross-machine direction, the MD sealing members **264** are positioned near the edges of the wet web **10**. In one particular embodiment, the MD sealing members **264** are moveable in the cross-machine direction in order to accommodate a range of possible wet web widths.

The illustrated CD sealing members **262** include a main upright wall section **266**, a transverse flange **268** projecting outwardly from a top portion **270** of the wall section, and a sealing blade **272** mounted on an opposite bottom portion **274** of the wall section **266** (**Figure 7**). The outwardly-projecting flange **268** thus forms opposite, upper and lower control surfaces **276** and **278** that are substantially perpendicular to the direction of movement of the sealing assembly **260**. The wall section **266** and flange **268** may comprise separate components or a single component as illustrated.

As noted above, the components of the sealing assembly **260** are vertically moveable between the retracted position shown in **Figures 4** and **5** and the operating position shown in **Figures 6** and **7**. In particular, the wall sections **266** of the CD sealing members **262** are positioned inward of the position control plates **250** and are slideable relative thereto. The amount of vertical movement is determined by the ability of the transverse flanges **268** to move between the bottom surfaces **226** of the upper support assemblies **222** and the top surfaces **242** of the lower support assemblies **240**.

The vertical position of the transverse flanges **268** and thus the CD sealing members **262** is controlled by activation of the pneumatic loading tubes **230** and **248**. The loading tubes **230** and **248** are operatively connected to a pneumatic source and to a control system (not shown) for the air press. Activation of the upper loading tubes **230**

creates a downward force on the upper control surfaces **276** of the CD sealing members **262** resulting in a downward movement of the flanges **268** until they contact the top surfaces **242** of the lower support assemblies **240** or are stopped by an upward force caused by the lower loading tubes **248** or the fabric tension. Retraction of the CD sealing members **262** is achieved by activation of the lower loading tubes **248** and deactivation of the upper loading tubes **230**. In this case, the lower loading tubes **248** press upwardly on the lower control surfaces **278** and cause the flanges **268** to move toward the bottom surfaces of the upper support assemblies **222**. Of course, the upper and lower loading tubes **230** and **248** can be operated at differential pressures to establish movement of the CD sealing members **262**. Alternative means for controlling vertical movement of the CD sealing members **262** can comprise other forms and connections of pneumatic cylinders, hydraulic cylinders, screws, jacks, mechanical linkages, or other suitable means. Suitable loading tubes **230** and **248** are available from Seal Master Corporation of Kent, Ohio.

As shown in **Figure 7**, a pair of bridge plates **279** span the gap between the upper support assemblies **222** and the CD sealing members **262** to prevent the escape of pressurized fluid. The bridge plates **279** thus define part of the air plenum chamber **214**. The bridge plates **279** may be fixedly attached to the facing surfaces **224** of the upper support assemblies **222** and slideable relative to the inner surfaces of the CD sealing members **262**, or vice versa. The bridge plates **279** may be formed of a fluid impermeable, semi-rigid, low-friction material such as LEXAN, sheet metal or the like.

The sealing blades **272** function together with other features of the air press **200** to minimize the escape of pressurized fluid between the air plenum **202** and the wet web **10** in the machine direction. Additionally, the sealing blades **272** are desirably shaped and formed in a manner that reduces the amount of fabric wear. In particular embodiments, the sealing blades **272** are formed of resilient plastic compounds, ceramic, coated metal substrates, or the like.

With particular reference to **Figures 6** and **8**, the MD sealing members **264** are spaced apart from one another and adapted to prevent the loss of pressurized fluid along the side edges of the air press **200**. **Figures 6** and **8** each show one of the MD sealing members **264**, which are positioned in the cross-machine direction near the edge of the wet web **10**. As illustrated, each MD sealing member **264** comprises a transverse support member **280**, an end deckle strip **282** operatively connected to the transverse support member **280**, and actuators **284** for moving the end deckle strip **282** relative to the

transverse support member **280**. The transverse support members **280** are normally positioned near the side edges of the wet web **10** and are generally located between the CD sealing members **262**. As illustrated, each transverse support member **280** defines a downwardly directed channel **281** (**Figure 8**) in which the end deckle strip **282** is mounted. Additionally, each transverse support member **280** defines circular apertures **283** in which the actuators **284** are mounted.

The end deckle strips **282** are vertically moveable relative to the transverse support members **280** due to the cylindrical actuators **284**. The coupling members **285** (**Figure 6**) link the end deckle strips **282** to the output shaft of the cylindrical actuators **284**. The coupling members **285** may comprise an inverted T-shaped bar or bars so that the end deckle strips **282** may slide within the channel **281**, such as for replacement.

As shown in **Figure 8**, both the transverse support members **280** and the end deckle strips **282** define slots to house a fluid impermeable sealing strip **286**, such as O-ring material or the like. The sealing strip **286** helps seal the air chamber **214** of the air press **200** from leaks. The slots in which the sealing strip **286** resides is desirably widened at the interface between the transverse support members **280** and the end deckle strips **282** to accommodate relative movement between those components.

A bridge plate **287** (**Figure 6**) is positioned between the MD sealing members **264** and the upper support plate **211** and fixedly mounted to the upper support plate **211**. The lateral portions of the air plenum chamber **214** (**Figure 7**) are defined by the bridge plate **287**. Sealing means such as a fluid impervious gasketing material is desirably positioned between the bridge plate **287** and the MD sealing members **264** to permit relative movement therebetween and to prevent the loss of pressurized fluid.

The actuators **284** suitably provide controlled loading and unloading of the end deckle strips **282** against the upper support fabric **206**, independent of the vertical position of the CD sealing members **262**. The load can be controlled exactly to match the necessary sealing force. The end deckle strips **282** can be retracted when not needed to eliminate all end deckle and fabric wear. Suitable actuators are available from Bimba Corporation. Alternatively, springs (not shown) may be used to hold the end deckle strips **282** against the upper support fabric **206** although the ability to control the position of the end deckle strips **282** may be sacrificed.

With reference to **Figure 6**, each end deckle strip **282** has a top surface or edge **290** disposed adjacent to the coupling members **285**, an opposite bottom surface or edge **292** that resides during use in contact with the upper support fabric **206**, and the lateral surfaces or edges **294** that are in close proximity to the CD sealing members **262**. The shape of the bottom surface **292** is suitably adapted to match the curvature of the vacuum box **204**. Where the CD sealing members **262** impinge upon the fabrics **206** and **208**, the bottom surface **292** is desirably shaped to follow the curvature of the fabric impingement. Thus, the bottom surface **292** has a central portion **296** that is laterally surrounded in the machine direction by spaced apart end portions **298**. The shape of the central portion **296** generally tracks the shape of the vacuum box **204** while the shape of the end portions **298** generally tracks the deflection of the fabrics **206** and **208** caused by the CD sealing members **262**. To prevent wear on the projecting end portions **298**, the end deckle strips **282** are desirably retracted before the CD sealing members **262** are retracted. The end deckle strips **282** are desirably formed of a gas impermeable material that minimizes fabric wear. Particular materials that may be suitable for the end deckle strips **282** include polyethylene, nylon, or the like.

The MD sealing members **264** are desirably moveable in the cross-machine direction and are thus desirably slideably positioned against the CD sealing members **262**. In the illustrated embodiment, movement of the MD sealing members **264** in the cross-machine direction is controlled by a threaded shaft or bolt **305** that is held in place by brackets **306** (**Figure 8**). The threaded shaft **305** passes through a threaded aperture in the transverse support member **280** and rotation of the shaft causes the MD sealing member to move along the shaft. Alternative means for moving the MD sealing members **264** in the cross-machine direction such as pneumatic devices or the like may also be used. In one alternative embodiment, the MD sealing members **264** are fixedly attached to the CD sealing members **262** so that the entire sealing assembly **260** is raised and lowered together (not shown). In another alternative embodiment, the transverse support members **280** are fixedly attached to the CD sealing members **262** and the end deckle strips **282** are adapted to move independently of the CD sealing members **262** (not shown).

The vacuum box **204** comprises a vacuum box cover **300** having a top surface **302** over which the lower support fabric **208** travels. The vacuum box cover **300** and the sealing assembly **260** are desirably gently curved to facilitate web control. The illustrated vacuum box cover **300** is formed, from the leading edge to the trailing edge in the machine

direction **205**, with a first exterior sealing shoe **311**, a first sealing vacuum zone **312**, a first interior sealing shoe **313**, a series of four high vacuum zones **314**, **316**, **318**, and **320** surrounding three interior shoes **315**, **317**, and **319**, a second interior sealing shoe **321**, a second sealing vacuum zone **322**, and a second exterior sealing shoe **323** (**Figure 7**). Each of these sealing shoes **315**, **317**, and **319** and vacuum zones **314**, **316**, **318**, and **320** desirably extend in the cross-machine direction across the full width of the web. The shoes **315**, **317**, and **319** each include a top surface desirably formed of a ceramic material to ride against the lower support fabric **208** without causing significant fabric wear. Suitable vacuum box covers and shoes may be formed of plastics, NYLON, coated steels or the like, and are available from JWI Corporation or IBS Corporation.

The four high vacuum zones **314**, **316**, **318**, and **320** are passageways in the cover **300** that are operatively connected to one or more vacuum sources (not shown) that draw a relatively high vacuum level. For example, the high vacuum zones **314**, **316**, **318**, and **320** may be operated at a vacuum of 0 to 25 inches of mercury vacuum, and more particularly about 10 to about 25 inches of mercury vacuum. As an alternative to the illustrated passageways, the cover **300** could define a plurality of holes or other shaped openings (not shown) that are connected to a vacuum source to establish a flow of pressurized fluid through the web. In one embodiment, the high vacuum zones **314**, **316**, **318**, and **320** comprise slots each measuring 0.375 inch in the machine direction and extending across the full width of the wet web. The dwell time that any given point on the web is exposed to the flow of pressurized fluid, which in the illustrated embodiment is the time over slots **314**, **316**, **318** and **320**, is suitably about 10 milliseconds or less, particularly about 7.5 milliseconds or less, more particularly 5 milliseconds or less, such as about 3 milliseconds or less or even about 1 millisecond or less. The number and width of the high pressure vacuum slots **314**, **316**, **318**, and **320** and the machine speed determine the dwell time. The selected dwell time will depend on the type of fibers contained in the wet web and the desired amount of dewatering.

The first and second sealing vacuum zones **312** and **322** may be employed to minimize the loss of pressurized fluid from the air press **200**. The sealing vacuum zones **312** and **322** are passageways in the cover **300** that may be operatively connected to one or more vacuum sources (not shown) that desirably draw a relatively lower vacuum level as compared to the four high vacuum zones **314**, **316**, **318**, and **320**. Specifically, the amount of vacuum that is desirable for the sealing vacuum zones is 0 to about 100 inches water column, vacuum.

The air press **200** is desirably constructed so that the CD sealing members **262** are disposed within the sealing vacuum zones **312** and **322**. More specifically, the sealing blade **272** of the CD sealing member **262** that is on the leading side of the air press **200** is disposed between, and more particularly centered between, the first exterior sealing shoe **311** and the first interior sealing shoe **313**, in the machine direction. The trailing sealing blade **272** of the CD sealing member **262** is similarly disposed between, and more particularly centered between, the second interior sealing shoe **321** and the second exterior sealing shoe **323**, in the machine direction. As a result, the sealing assembly **260** can be lowered so that the CD sealing members **262** deflect the normal course of travel of the wet web **10** and fabrics **206** and **208** toward the vacuum box **204**, which is shown in slightly exaggerated scale in **Figure 7** for purposes of illustration.

The sealing vacuum zones **312** and **322** function to minimize the loss of pressurized fluid from the air press **200** across the width of the wet web **10**. The vacuum in the sealing vacuum zones **312** and **322** draws pressurized fluid from the air plenum **202** and draws ambient air from outside the air press **200**. Consequently, an air flow is established from outside the air press **200** into the sealing vacuum zones **312** and **322** rather than a pressurized fluid leak in the opposite direction. Due to the relative difference in vacuum between the high vacuum zones **314**, **316**, **318**, and **320** and the sealing vacuum zones **312** and **322**, though, the vast majority of the pressurized fluid from the air plenum **202** is drawn into the high vacuum zones **314**, **316**, **318**, and **320** rather than the sealing vacuum zones **312** and **322**.

In an alternative embodiment which is partially illustrated in **Figure 9**, no vacuum is drawn in either or both of the sealing vacuum zones **312** and **322**. Rather, deformable sealing deckles **330** are disposed in the sealing vacuum zones **312** and **322** (only sealing zone **322** is shown) to prevent leakage of pressurized fluid in the machine direction. In this case, the air press **200** is sealed in the machine direction by the sealing blades **272** that impinge upon the fabrics **206** and **208** and the wet web **10** and by the fabrics **206** and **208** and the wet web **10** being displaced in close proximity to or contact with the deformable sealing deckles **330**. This configuration, where the CD sealing members **262** impinge upon the fabrics **206** and **208** and wet web **10** and the CD sealing members **262** are opposed on the other side of the fabrics **206** and **208** and the wet web **10** by deformable sealing deckles **330**, has been found to produce a particularly effective air plenum seal.

The deformable sealing deckles **330** desirably extend across the full width of the wet web **10** to seal the leading end, the trailing end, or both the leading and the trailing end of the air press **200**. The sealing vacuum zone **312** and **322** may be disconnected from the vacuum source when the deformable sealing deckle **330** extends across the full web width. Where the trailing end of the air press **200** employs a full width deformable sealing deckle **330**, a vacuum device or blow box may be employed downstream of the air press **200** to cause the web **10** to remain with one of the fabrics **206** or **208** as the fabrics **206** and **208** are separated.

The deformable sealing deckles **330** desirably either comprise a material that preferentially wears relative to the fabric **208**, meaning that when the fabric **208** and the material are in use the material will wear away without causing significant wear to the fabric **208**, or comprise a material that is resilient and that deflects with impingement of the fabric **208**. In either case, the deformable sealing deckles **330** are desirably gas impermeable, and desirably comprise a material with high void volume, such as a closed cell foam or the like. In one particular embodiment, the deformable sealing deckles **330** comprise a closed cell foam measuring 0.25 inch in thickness. Most desirably, the deformable sealing deckles **330** themselves become worn to match the path of the fabrics **206** and **208**. The deformable sealing deckles **330** are desirably accompanied by a backing plate **332** for structural support, for example an aluminum bar.

In embodiments where full width sealing deckles **330** are not used, sealing means of some sort are required laterally of the web. Deformable sealing deckles **330** as described above, or other suitable means known in the art, may be used to block the flow of pressurized fluid through the fabrics **206** and **208** laterally outward of wet web **10**.

The degree of impingement of the CD sealing members **262** into the upper support fabric **206** uniformly across the width of the wet web **10** has been found to be a significant factor in creating an effective seal across the web. The requisite degree of impingement has been found to be a function of the maximum tension of the upper and lower support fabrics **206** and **208**, the pressure differential across the web and in this case between the air plenum chamber **214** and the sealing vacuum zones **312** and **322**, and the gap between the CD sealing members **262** and the vacuum box cover **300**.

With additional reference to the schematic diagram of the trailing sealing section of

the air press **200** shown in **Figure 10**, the minimum desirable amount of impingement of the CD sealing member **262** into the upper support fabric **206**, h(min), has been found to be represented by the following equation:

$$h(\min) = \frac{T}{W}\left(\cosh\left(\frac{Wd}{T}\right) - 1\right);$$

where: T is the tension of the fabrics measured in pounds per inch;
W is the pressure differential across the web measured in psi; and
d is the gap in the machine direction measured in inches.

Figure 10 shows the trailing CD sealing member **262** deflecting the upper support fabric **206** by an amount represented by arrow "h". The maximum tension of the upper and lower support fabrics **206** and **208** is represented by arrow "T". The fabric tension can be measured by a model tensometer available from Huyck Corporation or other suitable methods. The gap between the sealing blade **272** of the CD sealing member **262** and the second interior sealing shoe **321** measured in the machine direction **205** and represented by arrow "d". The gap "d" of significance for the determining impingement is the gap on the higher pressure differential side of the sealing blade **272**, that is, toward the plenum chamber **214**, because the pressure differential on that side has the most effect on the position of the fabrics **206** and **208** and the web **10**. Desirably, the gap between the sealing blade **272** and the second exterior shoe **323** is approximately the same or less than gap "d".

Adjusting the vertical placement of the CD sealing members **262** to the minimum degree of impingement as defined above is a determinative factor in the effectiveness of the CD seal. The loading force applied to the sealing assembly **260** plays a lesser role in determining the effectiveness of the seal, and need only be set to the amount needed to maintain the requisite degree of impingement. Of course, the amount of fabric wear will impact the commercial usefulness of the air press **200**. To achieve effective sealing without substantial fabric wear, the degree of impingement is desirably equal to or only slightly greater than the minimum degree of impingement as defined above. To minimize the variability of fabric wear across the width of the fabrics, the force applied to the fabric is desirably kept constant over the cross machine direction. This can be accomplished with either controlled and uniform loading of the CD sealing members **262** or controlled position of the CD sealing members **262** and uniform geometry of the impingement of the CD sealing members **262**.

In use, a control system causes the sealing assembly **260** of the air plenum **202** to be lowered into an operating position. First, the CD sealing members **262** are lowered so that the sealing blades **272** impinge upon the upper support fabric **206** to the degree described above. More particularly, the pressures in the upper and lower loading tubes **230** and **248** are adjusted to cause downward movement of the CD sealing members **262** until movement is halted by the transverse flanges **268** contacting the lower support assemblies **240** or until balanced by fabric tension. Second, the end deckle strips **282** of the MD sealing members **264** are lowered into contact with or close proximity to the upper support fabric **206**. Consequently, the air plenum **202** and the vacuum box **204** are both sealed against the wet web **10** to prevent the escape of pressurized fluid.

The air press **200** is then activated so that pressurized fluid fills the air plenum **202** and an air flow is established through the web **10**. In the embodiment illustrated in **Figure 7**, high and low vacuums are applied to the high vacuum zones **314**, **316**, **318**, and **320** and the sealing vacuum zones **312** and **322** to facilitate air flow, sealing and water removal. In the embodiment of **Figure 9**, pressurized fluid flows from the air plenum **202** to the high vacuum zones **314**, **316**, **318**, and **320** and the deformable sealing deckles **330** seal the air press **200** in the cross machine direction. The resulting pressure differential across the wet web **10** and resulting air flow through the web **10** provide for efficient dewatering of the web **10**.

A number of structural and operating features of the air press **200** contribute to very little pressurized fluid being allowed to escape in combination with a relatively low amount of fabric wear. Initially, the air press **200** uses the CD sealing members **262** that impinge upon the fabrics **206** and **208** and the wet web **10**. The degree of impingement is determined to maximize the effectiveness of the CD seal. In one embodiment, the air press **200** utilizes the sealing vacuum zones **312** and **322** to create an ambient air flow into the air press **200** across the width of the wet web **10**. In another embodiment, deformable sealing deckles **330** are disposed in the sealing vacuum zones **312** and **322** opposite the CD sealing members **262**. In either case, the CD sealing members **262** are desirably disposed at least partly in passageways of the vacuum box cover **300** in order to minimize the need for precise alignment of mating surfaces between the air plenum **202** and the vacuum box **204**. Further, the sealing assembly **260** can be loaded against a stationary component such as the lower support assemblies **240** that are connected to the frame structure **210**. As a result, the loading force for the air press **200** is independent of

the pressurized fluid pressure within the air plenum **202**. The fabric wear is also minimized due to the use of low fabric wear materials and lubrication systems. Suitable lubrication systems may include chemical lubricants such as emulsified oils, debonders or other like chemicals, or water. Typical lubricant application methods include a spray of diluted lubricant applied in a uniform manner in the cross machine direction, an hydraulically or air atomized solution, a felt wipe of a more concentrated solution, or other methods well known in spraying system applications.

Observations have shown that the ability to run at higher pressure plenum pressures depends on the ability to prevent leaks. The presence of a leak can be detected from excessive air flows relative to previous or expected operation, additional operating noise, sprays of moisture, and in extreme cases, regular or random defects in the wet web including holes and lines. The leaks can be repaired by the alignment or adjustment of the air press sealing components.

In the air press **200**, uniform air flows in the cross-machine direction are desirable to provide uniform dewatering of a web **10**. Cross-machine direction flow uniformity may be improved with mechanisms such as tapered ductwork on the pressure and vacuum sides, shaped using computational fluid dynamic modeling. Because web basis weight and moisture content may not be uniform in the cross-machine direction, is may be desirably to employ additional means to obtain uniform air flow in the cross-machine direction, such as independently-controlled zones with dampers on the pressure or vacuum sides to vary the air flow based on sheet properties, a baffle plate to take a significant pressure drop in the flow before the wet web, or other direct means. Alternative methods to control CD dewatering uniformity may also include external devices, such as zoned controlled steam showers, for example a Devronizer steam shower available from Honeywell-Measurex Systems Inc. of Dublin, Ohio or the like.

Examples

The following examples are provided to give a more detailed understanding of the invention. The particular amounts, proportions, compositions and parameters are meant to be exemplary, and are not intended to specifically limit the scope of the invention.

Example 1

A 12-inch wide tissue was produced on an experimental tissue machine, having a fabric width of 22 inches, from a fibrous slurry comprised of an unrefined 50:50 fiber blend of bleached kraft northern softwood fibers and bleached kraft eucalyptus fibers. The tissue was formed using a stratified, three-layer headbox with the slurry being deposited from each stratum to form a blended sheet having a nominal basis weight of 19 gsm. The headbox injected the slurry between two Lindsay Wire 2164B forming fabrics, in a twin wire forming section, with a suction roll former. To control strength, 1000 ml/minute of Parez 631 NC at 6 percent solids was added to the stock prior to the forming process.

While disposed between the two forming fabrics and traveling at 1000 feet per minute (fpm), the embryonic wet web was transported over four vacuum boxes operating with respective vacuum pressures of approximately 11, 14, 13 and 19 inches of mercury vacuum. The embryonic wet web, still contained between the two forming fabrics, passed through an air press including an air plenum and a collection box that were operatively associated and integrally sealed with one another. The air plenum was pressurized with air at approximately 150 degrees Fahrenheit to 15 pounds per square inch gauge, and the collection box was operated at approximately 11 inches of mercury vacuum. The wet web was exposed to the resulting pressure differential of approximately 41.5 inches of mercury and air flow of 68 SCFM per square inch for a dwell time of 7.5 milliseconds over four slots, each 3/8" in length. The consistency of the wet web was approximately 30 percent just prior to the air press and 39 percent upon exiting the air press.

The dewatered wet web was then transferred using a vacuum pickup shoe operating at approximately 10 inches of mercury vacuum onto a three-dimensional fabric, a Lindsay Wire T-216-3 TAD fabric. A silicon emulsion in water was sprayed onto the sheet side of the T-216-3 fabric just prior to transfer from the forming fabric to facilitate the eventual transfer to the Yankee dryer. The silicone was applied at a flow rate of 400 ml/minute at 1.0% solids. The TAD fabric was thereafter pressed against the surface of a Yankee dryer with a conventional pressure roll operating at a maximum pressing pressure of 350 pli. The fabric was wrapped over about 39 inches of the Yankee dryer surface by a transfer roll which was unloaded and slightly removed from the Yankee dryer.

The wet web was adhered to the Yankee dryer using an adhesive mixture of polyvinyl alcohol AIRVOL 523 made by Air Products and Chemical Inc. and sorbitol in water applied by four #6501 spray nozzles by Spraying Systems Company operating at

approximately 40 psig with a flow rate of about 0.4 gallons per minute (gpm). The spray had a solids concentration of about 0.5 weight percent. The dried web was creped from the Yankee dryer at a final dryness of approximately 92% consistency and wound on a core. The product was then converted into 2-ply bathroom tissue using standard techniques. Results obtained for **Example 1** are shown below in **Table 1**.

Table 1

Test	Units	Example 1 Invention (Creped)	Example 2 Invention (Uncreped)	Example 3 (Comparative)	Example 4 (Comparative)
Roll Firmness	0.001"	104	140	134	178
Roll Diameter	Mm	126	128	125	125
Sheet Count		253	180	280	198
Core OD	Mm	40	40	46	46
Caliper (2kPa, 8 plies)	Microns	1667	2402	1288	1719
MD Strength	g/3"	1739	1911	2285	1719
MD Stretch	%	14	13	22	15
CD Strength	g/3"	972	1408	718	700
GMT	g/3"	1300	1640	1281	1097
Bone Dry Roll Weight	G	133	95	158	106
Bone Dry Basis Weight	g/m^2	19.1	18.8	20.6	20.4
Absorbent Capacity	G	97.4	117.2	79.0	97.0
Absorbent Capacity	g(h$_2$0)/g(fiber)	11.8	14.1	10.8	11.0

Example 2

A 12-inch wide tissue was produced on an experimental tissue machine, having a fabric width of 22 inches, from a fibrous slurry comprised of an unrefined 50:50 fiber blend of bleached kraft northern softwood fibers and bleached kraft eucalyptus fibers. The tissue was formed using a stratified, three-layer headbox with the slurry being deposited from each stratum to form a blended sheet having a nominal basis weight of 19 gsm. The headbox injected the slurry between two Lindsay Wire 2164B forming fabrics, in a twin wire forming section, with a suction roll former. To control strength, 1000 ml/minute of

Parez 631 NC at 6 percent solids was added to the stock prior to the forming process.

While disposed between the two forming fabrics and traveling at 1000 feet per minute (fpm), the embryonic wet web was transported over four vacuum boxes operating with respective vacuum pressures of approximately 11, 14, 13 and 19 inches of mercury vacuum. The embryonic wet web, still contained between the two forming fabrics, passed through an air press including an air plenum and a collection box that were operatively associated and integrally sealed with one another. The air plenum was pressurized with air at approximately 150 degrees Fahrenheit to 15 pounds per square inch gauge, and the collection box was operated at 11 inches of mercury vacuum. The wet web was exposed to the resulting pressure differential of approximately 41.5 inches of mercury and air flow of 68 SCFM per square inch for a dwell time of 7.5 milliseconds over four slots, each with 3/8" length. The consistency of the wet web was approximately 30 percent just prior to the air press and 39 percent upon exiting the air press.

The dewatered wet web was then rush transferred using a vacuum pickup shoe operating at approximately 10 inches of mercury onto a three-dimensional fabric, a Lindsay Wire T-216-3 TAD fabric, traveling 20% percent slower than the forming fabrics. A silicone emulsion in water was sprayed onto the sheet side of the T-216-3 fabric just prior to transfer from the forming fabric to facilitate the eventual transfer to the Yankee dryer. The TAD fabric was thereafter pressed against the surface of a Yankee dryer with a conventional pressure roll operating at a maximum pressing pressure of 350 pli. The fabric was wrapped over about 39 inches of the Yankee dryer surface by a transfer roll which was unloaded and slightly removed from the Yankee dryer.

The wet web was adhered to the Yankee in a controlled manner using an interfacial control mixture comprised, on a percent active solids basis, of approximately 26 percent polyvinyl alcohol, 46 percent sorbitol, and 28 percent of Hercules M1336 polyglycol applied at a dose of between 50 and 75 mg/m^2. The compounds were prepared in an aqueous solution having less than 5 percent solids by weight. The wet web was dried on the Yankee dryer to approximately 90% consistency and then "peeled" from the Yankee dryer by applying sufficient winding tension to remove the dried web just prior to the creping blade. The dried web was then wound on a core without additional pressing. The product was then converted into 2-ply bathroom tissue using standard techniques. Results obtained for **Example 2** are shown above in **Table 1**.

Example 3 (Comparative)

A wet web was formed from a 50:40:10 blend of bleached kraft northern softwood, bleached kraft eucalyptus and softwood BCTMP fibers using a Fourdrinier former operating at approximately 3500 fpm. The resulting wet web at a basis weight of approximately 20 gsm was transferred from the forming fabric to a standard wet-press felt (using a couch roll). The wet web was carried to a 15 foot Yankee dryer and transferred to the Yankee dryer using standard techniques. The wet web was dried on the Yankee dryer using standard techniques and removed from the dryer at approximately 95% consistency using a creping blade.

To further increase the caliper, the web was transferred over an open draw to a second Yankee dryer (this dryer operating without the normal hood) and adhered to the Yankee dryer using a Latex adhesive. The wet web was then creped again and wound on a core. The product was then converted into 2-ply bathroom tissue using standard techniques. The process used in this example is known as the single re-creped process U.K. patent documents GB 2179949 B, GB 2152961 A, and GB 2179953 B, which are incorporated herein by reference. Results obtained for **Example 3** are shown above in **Table 1**.

Example 4 (Comparative)

A wet web was formed from a 65:35 blend of bleached kraft northern softwood and bleached kraft eucalyptus fibers. The wet web was formed using a twin wire former in a layered configuration with the eucalyptus on the outside (air side) of the wet web. The wet web was dewatered to a consistency of approximately 27 percent using conventional vacuum dewatering technology and then throughdried using standard technology to a consistency of approximately 90 percent. The wet web was then transferred to a Yankee dryer, adhered using PVA as the adhesive, and dried to a consistency of 97 percent. The dried web was then wound on a core. The product was then converted into 2-ply bathroom tissue using standard techniques. Results obtained for **Example 4** are shown below in **Table 1**.

The data of **Table 1** clearly shows the improvement in sheet/roll properties that can be achieved using this invention. In the creped form (**Example 1**), the product of this invention yielded bath tissue that exhibited higher sheet caliper, 1667 microns versus 1288, than that of the control (**Example 3**) despite the additional re-creping step employed specifically to increase the bulk of the control. Without this re-creping step, the difference would be even larger, as the re-creping step typically adds about 30% more caliper. From the standpoint of roll properties, this additional caliper allowed the removal of 27 sheets (from 280 count to 253 count) while maintaining the same roll diameter. In fact, the rolls produced using this invention were firmer at the same roll diameter (104 versus 134 with lower numbers indicating greater firmness) despite the reduction in sheet count. Considered as a whole, the invention allowed a reduction in roll weight from 158 grams to 133 grams (16%) while producing superior roll properties.

The improvement in roll properties is even more striking when the uncreped example (**Example 2**) is considered. Here the sheet count was reduced to 180 sheets (again versus 280 for the control) while maintaining roll diameter and firmness. In this case the roll weight was reduced by 40%.

Alternately, the product of this invention was compared to creped throughdried, the product described in **Example 4**. It is clear the products have roughly equal properties in terms of roll bulk etc. In fact, the throughdried example showed a relatively low firmness, indicating the product of this invention is even better than that of the throughdried process.

Example 5

A wet web was formed from a fiber blend of 50:30:20 southern bleached kraft pine, bleached kraft northern softwood, and bleached kraft eucalyptus on an experimental tissue machine running approximately 50 fpm. The resulting wet web, at an approximate basis weight of 41 grams per meter square, was carried on the forming fabric and then transferred to a T-216-3 molding fabric. At the transfer point, the embryonic wet web was passed through an air press including an air plenum and a collection box that were operatively associated and (integrally) sealed with one another. At this point, the wet web was dewatered from the post forming consistency of approximately 10% to 32-35% consistency. The wet web was then carried to a Yankee dryer where it was transferred to the Yankee dryer, adhered using polyvinyl alcohol applied using standard spray nozzles and dried to 55% consistency. The web was then transferred to afterdriers for final drying

and wound on a core. The resulting dried web was then embossed using a butterfly embossing pattern to obtain the final one-ply towel product. Results obtained for **Example 5** are shown below in **Table 2**.

Example 6

A fiber blend of 65:35 bleached kraft southern softwood and softwood BCTMP was formed into a wet web at a machine speed of 250 fpm using a Fourdrinier style former. The resulting wet web, at an approximate basis weight of 50 grams per square meter, was transferred to a standard wet-pressing felt and conveyed to a Yankee dryer. The wet web was transferred to the Yankee dryer at a pressure roll nip using standard wet-pressing techniques. The wet web was adhered to the dryer using polyvinyl alcohol and creped at approximately 55 percent consistency. The dried web was then conveyed over an open draw to a series of can dryers where it was dried to approximately 95 percent consistency and wound on a core. The product was then converted into 1-ply towels using standard techniques. Results obtained for **Example 6** are shown below in **Table 2**.

Table 2

Test	Units	Example 5 Invention	Example 6 (Comparative)
Roll Firmness	inches	0.191	0.277
Roll Diameter	inches	5.3	5.0
Sheet Count		80	85
Core OD	mm	42	37
Caliper - 10 sheet	inches	0.252	0.195
MD Strength	g/3"	2934	2750
MD Stretch	%	13.2	7.8
CD Strength	g/3"	1420	1086
CD Stretch	%	8.1	7.3
GMT	g/3"	2041	1728
As Is Basis Weight	g/m^2	41.3	50.9
Absorbent Capacity	g	2.56	1.73
Absorbent Capacity	$g(h_20)/g(fiber)$	5.86	3.84

Table 2 clearly shows the product advantages inherent to this invention. The

paper towels produced using this invention have superiority to the heavy wet-creped control in terms of caliper and absorbency despite a 19% reduction in basis weight. Additionally, the product of this invention has higher CD stretch which gives the towel added "toughness" in use. As finished product, the rolls produced using this invention were of higher diameter (5.3 inches vs. 5.0) and more firm (0.191 vs. 0.277). Again this was accomplished despite a 19% reduction in roll weight since sheet size and count were fixed.

Example 7

A wet web was formed using a fiber blend of 50:50 bleached kraft northern softwood and bleached kraft eucalyptus using the forming equipment and configuration described in **Example 1**. In this case, the machine speed was 2500 fpm. The resulting wet web, at an approximate basis weight of 20 pounds/2880 ft2, was passed through four vacuum boxes at 19.8, 19.8, 22.6, and 23.6 inches of mercury, respectively. The resulting wet web was then sent through the additional integrally-sealed dewatering system also described in **Example 1**. The air press was set to maintain a pressure of 15 psig in the plenum and pre and post air press samples were taken for consistency measurement. Results obtained for **Example 7** are shown below in **Table 3**.

Example 8

The experiment of **Example 7** was repeated except this time the air press was reconfigured to eliminate the integral seal between the air press plenum and the associated collection box. Specifically, the sealing load and hence the impingement of the cross-machine sealing blades was reduced until a leak between the plenum and the collection box became apparent. At this point, the air press plenum/collection box arrangement was set to a nominal 0.1 inch gap, though it was not possible to actually see the spacing between the plenum and the box as it was occupied by the fabrics and the wet web. The air flow to the plenum increased to the maximum obtainable from the compressor and a post dewatering consistency sample taken. Results obtained for **Example 8** are shown below in **Table 3**.

Table 3

Test	Units	Example 7	Example 8 (Comparative)
Post Dewatering Consistency	%	34.2	32.1
Pre Dewatering Consistency	%	26.8	26.8
Water Removed	lb. water / lb. fiber	0.81	0.61

As illustrated in **Table 3**, any reduction in the integral seal results in a significant loss in the dewatering capability of the air press. Specifically, approximately 25% less water was removed (0.61 pounds/pound versus 0.81) when the integral seal was lost, even though the plenum and collection box were still in apparent contact with the fabrics. The associated 2% loss in post dewatering consistency would translate to approximately a 10% reduction in machine speed on a machine that was speed limited due to drying limitations. Such a limitation would be expected on a wet-pressed machine that was converted to the configuration of this invention.

The previous experiment was an attempt to illustrate the best possible result that might be obtained using known technologies, such as that described in U.S. Patent 5,230,776 to Valmet Corporation. In actual practice, it is unlikely the equipment could even be operated as described above due to the excessive noise generated during the experiment and the jet of air issuing form the non-integrally sealed dewatering equipment. Though not specified, in actual practice, it is thought that the equipment described in U.S. Patent 5,230,776 would be operated with a gap of 1 inch or more, a condition under which significantly more dewatering would be lost and much greater air consumption would result. In practical terms, such inefficiency leads to so much additional energy consumption and reduced speed as to render such technology unsuitable for commercial equipment.

Example 9

A wet web was formed, with a fiber blend of 50:50 bleached kraft northern softwood and bleached kraft eucalyptus, into a 20 gsm sheet at 2000 fpm as described in **Example 1**. The wet web was then vacuum dewatered using 4 vacuum boxes at vacuum levels of approximately 18, 18, 17 and 21 inches respectively. A vacuum box consistency

sample was taken. The results are shown in **Table 4**.

Example 10

The experiment of **Example 9** was repeated but with a steam "blow box" (Devronizer) added to increase the dewatering. The steam box was not integrally sealed to the vacuum box, and it thus thought to be similar to an apparatus disclosed in U.S. Patent 5,230,776. Steam flow to the Devronizer was approximately (300 pounds) per hour. Again a consistency sample was taken to determine the increase attributable to the addition of the steam blow box. The results are shown in **Table 4**.

Example 11

The experiment of **Example 8** was repeated but with the integrally sealed air press of **Example 1** added to the process. The air press was operated at 15 psig plenum pressure and a vacuum level of 17 inches of mercury. Again, a consistency sample was taken to determine the increase attributable to the addition of the integrally sealed air press. The results are shown in **Table 4**.

Table 4

ID	Consistency %
Example 9	24.2
Example 10	24.8
Example 11	33.3

The data of **Table 4** clearly shows the significant gain in consistency associated with using the integrally-sealed air press relative to the use of the steam blow box. The blow box increased the consistency by 0.6% while the integrally sealed air press increased the consistency by an additional 8.5% beyond that achieved by the steam blow box. Since the wet web was already dewatered over four vacuum boxes to reach the 24.2% consistency (**Example 9**), it is not practical to add enough vacuum and/or steam blow boxes to raise the consistency to a level where commercially viable speeds can be achieved. However, with the addition of the integrally-sealed air press (**Example 11**), the consistency can be raised to a level where commercial speeds are obtainable with a modified wet-pressed design.

The foregoing detailed description has been for the purpose of illustration. Thus, a number of modifications and changes may be made without departing from the spirit and scope of the present invention. For instance, alternative or optional features described as part of one embodiment can be used to yield another embodiment. Additionally, two named components could represent portions of the same structure. Further, various alternative process and equipment arrangements may be employed, particularly with respect to the stock preparation, headbox, forming fabrics, web transfers, creping and drying. Therefore, the invention should not be limited by the specific embodiments described, but only by the claims and all equivalents thereto.